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## ROBOTIC DESIGN FOR AN AUTOMATED URANIUM SOLUTION ENRICHMENT SYSTEM

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### ABSTRACT

A method to automate solution enrichment analysis by gamma-ray spectroscopy is being developed at Los Alamos National Laboratory. Both passive and x-ray fluorescence (XRF) analyses will be remotely performed to determine the amounts of  $^{235}\text{U}$  and total uranium in sample containers. A commercial laboratory robot will be used to process up to 40 batch and 8 priority samples in an unattended mode. Samples will be read by a bar-code reader to determine measurement requirements, then assayed by either or both of the gamma-ray and XRF instruments. The robot will be responsible for moving the sample containers and operating all shield doors and shutters. In addition to reducing hardware complexity, this feature will also allow manual operation of the instruments if the robot fails. This automated system will reduce personnel radiation exposure and increase the reliability and repeatability of the measurements.

### MEASUREMENT NEED

As part of a general quality control and safeguards upgrade, the Portsmouth Gaseous Diffusion Plant in Portsmouth, Ohio has contracted with Los Alamos National Laboratory (LANL) to provide two automated nondestructive-assay instruments to analyze the enrichment of uranium solutions by gamma-ray spectroscopy. The instruments are expected to analyze around 700 items per month. Most items will be processed in a batch mode (first in, first out). Batch capacity will be 38 samples, running in an unattended mode. Samples can also be processed on a priority basis. Placing a sample in any one of eight priority levels will interrupt the batch mode and start processing on the highest priority sample. This overall process is shown in Fig. 1.

### MEASUREMENT COLLECTION

Sample solutions, drawn from various process streams in the plant, will be brought to one of two laboratories and pipetted into 200-mL plastic vials. Accurate solution quantities are required to determine the total uranium in solution. A bar code will be applied to the side of the vial and will correspond to a data base with the location, date, time, technician, etc. A portion of this information will be loaded into the process computer that controls the robot and performs the assay measurement. Vials are then placed in a sample tray inside the robotic enclosure. Opening the loading doors will suspend robotic motion. To eliminate a potential source of operator error, samples are not keyed to a given tray location. Priority and

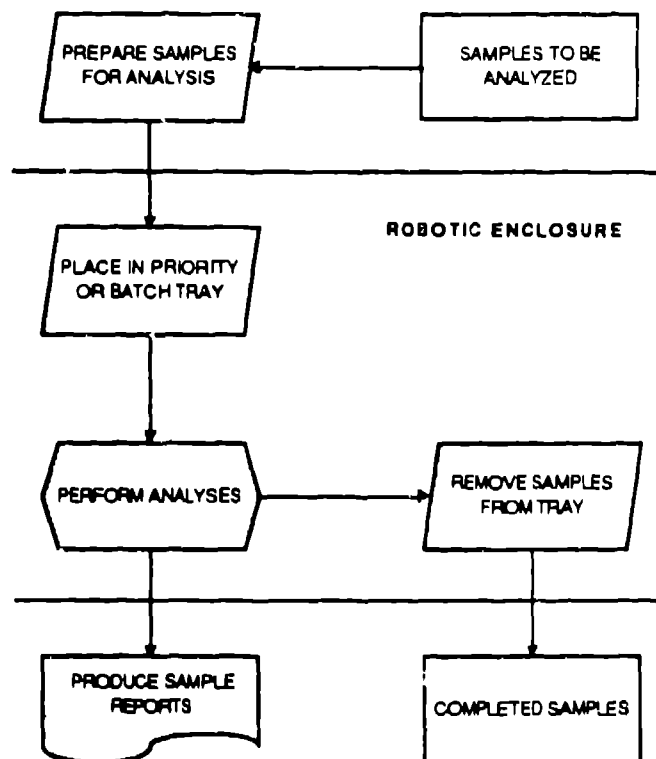


Fig. 1. Solution enrichment system measurement process.

batch samples are identified before analysis by an automatic bar-code reader.

### MEASUREMENT OPERATION

The overall sequence of operations of the robot is controlled by the process computer. Instructions are passed to the robot controller by a "move" command and a "locate" command. Move commands will be interpreted by the robot controller that will execute the proper robot arm and manipulator sequences to accomplish the move. These sequences are broken down into pick, go to, and place subprograms. Locate commands are used to sense the presence of objects.

After samples have been assayed and unloaded and new samples have been loaded, the operator will instruct the process computer to begin/resume operation. If no priority samples are present, batch processing will proceed in sequential order. Batch processing will be completed when two or more

tray locations are found to be empty. This is accomplished by a touch-sensitive feedback sensor on the robot manipulator.

Placing one or more vials in the priority slots will suspend batch processing. All priority slots are continuously sensed by the process computer for the presence of a vial. Status lights for each priority position indicate one of three conditions:

- empty slot,
- vial assay in progress, or
- assay completed.

The priority slots are preferentially serviced, with slot 1 having the highest priority down to slot 8 with the lowest.

After loading, the process computer will instruct the robot to move the appropriate vial to be assayed to a rotator positioned in front of a bar-code reader. After receiving the move completed signal from the robot, the process computer will rotate the sample several times while reading the bar code. Now knowing the sample ID, the process computer will query the data base to determine the appropriate measurements to be taken. Samples may require either or both assay measurements (passive and XRF). Subsequent measurement data will be associated with the sample ID. This process is shown in Fig. 2. The process computer will display a completed signal to the operator when a priority sample or all batch samples are analyzed.

To reduce the complexity of the instrumentation, the robot will move two sets of sliding lead-shield covers on each instrument (passive and XRF) and operate the XRF shutter mechanism. This eliminates the need for additional motors

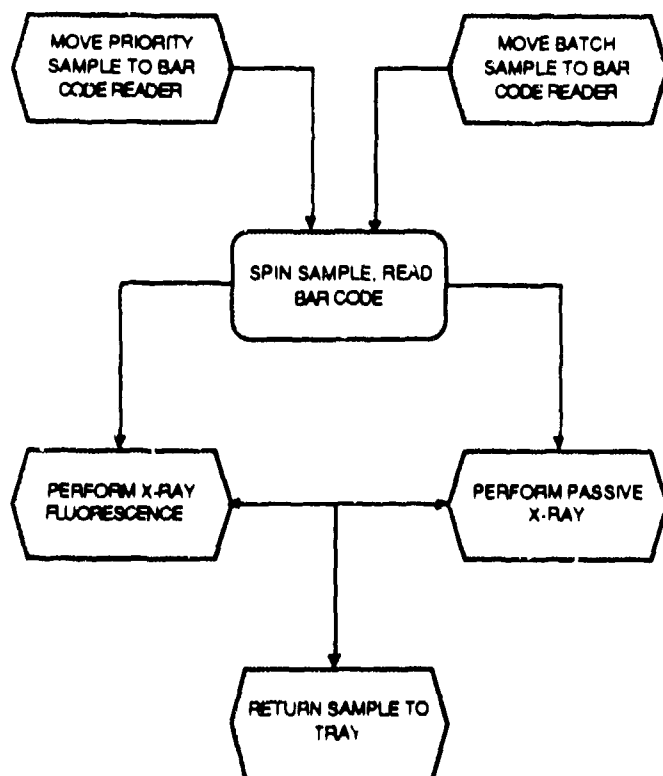


Fig. 2. Robot measurement sequence.

and solenoids and their controllers. The sequence of steps for the XRF measurement is given in Fig. 3. For the passive measurement, the sequence is similar except that the XRF steps are omitted.

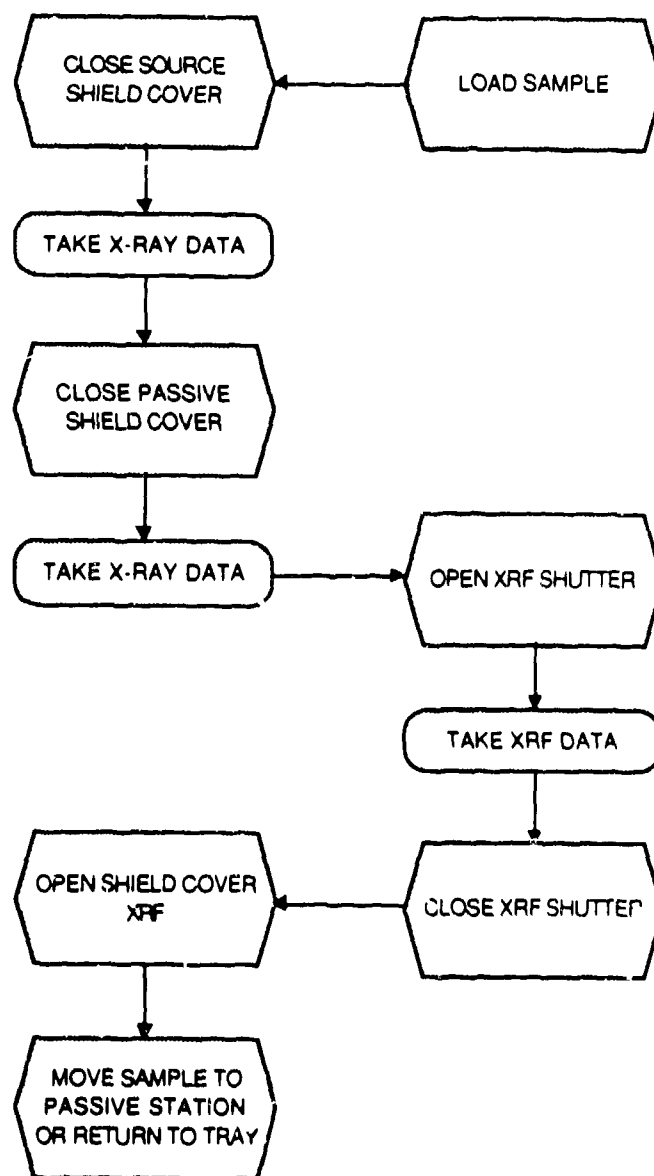


Fig. 3. XRF measurement sequence.

## ROBOT POSITIONAL TOLERANCES

For assay measurement repeatability, the sample vials must be located within 0.001 in. vertically and 0.002 in. laterally over the detector heads and the sources in both shield covers must be positioned within 0.005 in. vertically and 0.010 in. laterally. To accurately position the vials, a sample holder has been designed with sloping sides to allow final alignment. This will allow the vial to be placed in the holder within 0.010 in. and settle in for the final alignment. As the shield cover will move on sliding tracks, vertical alignment is assured; lateral positioning to within 0.010 in. will need to be accomplished by the robot. To assure that the 0.010-in. requirement

can be reliably met, a robot with a positional repeatability of 0.005 in. was selected.

## ROBOT ENCLOSURE

A positive-pressure enclosure drawing in filtered air from an outside source will protect the robotic system and the assay instruments from the dust and acid environment of the laboratory. A sketch of this design is shown in Fig 4. The clear access doors will be interlocked to the robot controller. Opening the loading-access doors will place the robot arm/gripper in a controlled stop. The operator will restart the robot from the process computer after the doors are closed.

Status lights on the front panel will indicate when the robotic system is in either batch mode processing, priority processing, or an error condition is present (operator call). The process computer will communicate to the robot controller the status states to display.

Inside the enclosure at about waist level is an instrument shelf that provides support for the two 300-lb detector head assemblies, the sample tray and its priority display panel, a drip pan, and a bar-code reader. Slots in the shelf are provided to allow direct slide-out removal of the instrument head. A bottom shelf is provided in the center of the unit for the robot controller. Liquid-nitrogen dewars are located on either side of the robot controller, resting on floor jacks. This configuration is shown in Fig 5.

## AVAILABILITY CONCERNS

To increase the amount of time the unit is available, an uninterruptable power supply (UPS) will be connected to the



Fig 4. LANL solution enrichment system

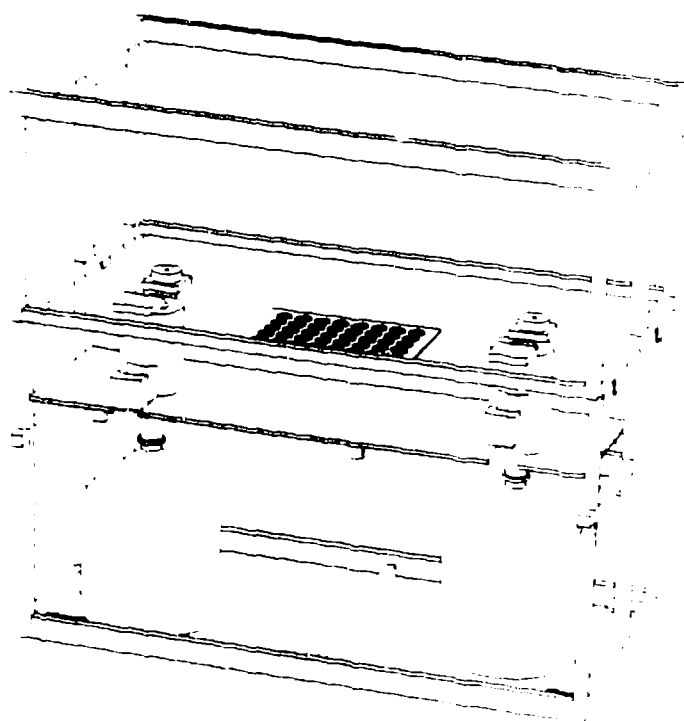


Fig 5. Solution enrichment system configuration layout.

robot and the process computer to provide power during intermittent outages ( $<15$  min). In the event of an extended outage, the UPS will signal the process computer to safely stop the current operations, putting down safely any container currently held in the gripper.

## SUMMARY

Automating the solution enrichment analysis by gamma-ray spectroscopy will improve the reliability and repeatability of the assay over existing manual methods. Both passive and XRF analyses will be remotely performed to determine the amount of  $^{235}\text{U}$  and total uranium in sample containers. A commercial laboratory robot will be used to process up to 40 batch and 8 priority samples in an unattended mode. Operator involvement per sample will be reduced, lowering the assay cost. This permits plant operators to increase their sampling rates and obtain better quality control over processing operations. Future upgrades or changes in the assay method can be easily accommodated by revising the process computer commands and/or the robot controller instruction sequences. The robot can be reprogrammed on site by a touch keypad or by downloading instructions from the process computer. In the health physics area, personnel radiation exposure per sample should also be reduced.

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